

A.2 Major Decision Variables

The major decision variables include capacity of conventionals, renewables, and storage along with transmission; and dispatch of conventional capacity and storage. Unless otherwise noted, capacity variables are expressed in megawatts and energy variables are expressed in megawatt-hours.

Wind Variables

- $WturN_{c,i,l,wscp}$ — new⁴ wind capacity that will access pre-2006⁵ transmission lines at a cost associated with step $wscp$ of the transmission supply curve.⁶
- $WturTN_{c,i,l}$ — New wind turbine capacity that can be transmitted only on new transmission lines dedicated to wind transmission from region i to another region.
- $Wtur_inregion_{c,i,l}$ — New wind turbine capacity whose transmitted electricity will move on new transmission lines dedicated to wind from a class c wind site within region i to a load center also within region i .
- $WN_{c,i,j,l}$ — Wind energy sent from new turbines in region i to region j that must be accommodated on pre-2006 lines.
- $WTN_{c,i,j,l}$ — Wind energy sent from new turbines in region i to region j on new lines dedicated to wind.
- $Welec_inregion_{c,i,l,escp}$ Wind energy sent from new turbines in region i to a load center also within region i .
- $WS_{n,m}$ — The amount by which the wind power supplied to balancing area n exceeds the electricity demand in balancing area n in time-slice m .
- WCt_g — New national wind turbine capacity in bin g ; used for estimating the increase in wind turbine price with rapid world growth.
- $WCtinst_{i,ginst}$ — New wind turbine capacity from bin $ginst$ in region i ; used for estimating the increase in installation costs with rapid regional growth.
- $WNSC_{i,l,wscp}$ — New wind turbine capacity to be connected to the grid in region i from step $wscp$ of the supply curve, which provides the cost of building transmission from region i to the grid.

CSP Variables

- $CSpturN_{cCSP,i,cspscp}$ — new CSP capacity that will access pre-2006 transmission lines at a cost associated with step $cspscp$ of the transmission supply curve.
- $CSpturTN_{cCSP,i,j}$ — New CSP capacity that can be transmitted only on new transmission lines dedicated to CSP transmission from region i to another region.
- $CSptur_inregion_{cCSP,i}$ — New CSP capacity whose transmitted electricity will move on new transmission lines dedicated to CSP from a class $cCSP$ site within region i to a load center also within region i .
- $CSPN_{cCSP,i,j}$ — CSP energy sent from new plants in region i to region j that must be accommodated on pre-2006 lines.

⁴New capacity means capacity built in this period, i.e. in this period's optimization run of the linear program.

⁵To reduce confusion, in the detailed model description, existing prior to the start of the model (2006) will be called "pre-2006" while existing prior to the start of a given period will be called "existing."

⁶In the model itself, $WturN$, $WturTN$, WN , and WTN are not actually subscripted with c . Instead, to reduce the solve time, a parameter $class_{c,i,l}$ keeps track of which class is the most attractive available in each region in that period. For this document, $class_{c,i,l}$ has been elided and c has been integrated directly into the variables for simplicity.

- $\text{CSPTN}_{cCSP,i,j}$ — CSP energy sent from new plants in region i to region j on new lines dedicated to CSP.
- $\text{CSPelec_inregion}_{cCSP,i,escp}$ — CSP energy sent from new plants in region i to a load center also within region i .
- $\text{CSPS}_{n,m}$ — The amount by which the CSP power supplied to balancing area n exceeds the electricity demand in balancing area n in time-slice m .
- CSPCt_{gCSP} — New national CSP capacity in bin $gCSP$; used for estimating the increase in CSP price with rapid world growth.
- $\text{CSPCt}_{inst,i,gCSPinst}$ — New CSP capacity from bin $gCSPinst$ in region i ; used for estimating the increase in installation costs with rapid regional growth.
- $\text{CSPNSC}_{cspscp,i}$ — New CSP capacity to be connected to the grid in region i from step $cspscp$ of the supply curve, which provides the cost of building transmission from region i to the grid.
- $\text{ReT}_{n,p}$ — New transmission capacity for wind or CSP (renewable) between balancing areas n and p .

Conventional Variables

- $\text{CONV}_{n,q}$ — Dispatchable (primarily conventional) capacity of technology q in balancing area n .⁷
- $\text{CONVgen}_{n,m,q}$ — Conventional generation in time-slice m by technology q in balancing area n .
- $\text{CONVP}_{n,m,q}$ — Peaking conventional generation in time-slice m by technology q in balancing area n .
- $\text{CCt}_{g,q}$ — Growth in conventional capacity per year.
- $\text{SR}_{n,m,q}$ — Spinning reserve capacity in time-slice m by technology q in balancing area n .
- $\text{QS}_{n,q}$ — Available quickstart capacity of technology q in balancing area n .
- $\text{CONVT}_{n,p,m}$ — New transmission capacity for conventionals between balancing areas n and p .
- $\text{GeoBin}_{geoclass,n}$ — New geothermal capacity by step on resource supply curve.
- $\text{GeoEGSBin}_{egsclass,n}$ — New EGS capacity by step on resource supply curve.
- $\text{BioBin}_{bioclass,n}$ — Biomass consumption by step on resource supply curve.
- $\text{BioGeneration}_{bioclass,n}$ — Generation from dedicated biomass plants by step on resource supply curve.
- $\text{CofireGen}_{bioclass,n}$ — Biomass-generated energy from coal-cofiring plants by step on resource supply curve.

⁷Note that, for conventional capacity, the decision variable is not the new capacity, but the total capacity. This was done to simplify bookkeeping and to eliminate the need for vintaging of capacity built after 2006. To ensure that conventional capacity from previous periods (minus retirements) is built, a lower bound is specified for each of these variables. Thus the objective function value from the LP includes the full cost of all conventional capacity as well as the cost of their operation over the 20-year investment analysis period. This does not affect the amount of conventional capacity installed, because anything built beyond the lower bound must pay the marginal cost of new capacity. It does affect the amount of conventional fuel purchased, in that any capacity built in previous periods will have the same heatrate as the new capacity.

Storage Variables

- $\text{STOR}_{n,st}$ — Load-sited storage capacity of technology st in balancing area n .
- $\text{STORin}_{n,m,st}$ — Energy used to charge load-sited storage in time-slice m .
- $\text{STORout}_{n,m,st}$ — Energy discharged from load-sited storage in time-slice m .
- $\text{STORor}_{n,m,st}$ — Operating reserve capacity of load-sited storage in time-slice m .
- $\text{WSTOR}_{i,st}$ — Wind-sited storage capacity of technology st in resource region i .
- $\text{WSTORin_grid}_{i,m,st}$ — Grid energy sent to charge wind-sited storage in region i in time-slice m .
- $\text{WSTORin_wind}_{c,i,m,st}$ — Energy sent directly from wind turbines to charge wind-sited storage in time-slice m .
- $\text{WSTORout_source}_{i,m,st}$ — Energy discharged from wind-sited storage in source region i in time-slice m .
- $\text{WSTORout_dest}_{i,m,p}$ — Energy discharged from wind-sited storage in source region i to destination balancing authority p in time-slice m .
- $\text{WSTORout_inregion}_{i,m,p}$ — Energy discharged from wind-sited storage in source region i and consumed to a load center also within region i .
- $\text{WSTORor}_{n,m,st}$ — Operating reserve capacity of wind-sited storage in time-slice m .

Miscellaneous Variables

- $\text{TPCAN}_{n,p}$ — Transmission capacity between balancing areas n and p .
- $\text{TPCACT}_{tpca,g}$ — Growth in new transmission capacity per year.
- $\text{CONTRACTcap}_{n,p}$ — Firm capacity contracted from balancing authority n to p .
- $\text{COALLOWSUL}_{n,q}$ — Annual generation from low-sulfur coal by (coal-burning) technology q .
- RPS_shortfall — Unmet amount of RPS requirement. A penalty is assessed on the shortfalls in the objective function.
- $\text{St_RPS_shortfall}_{states}$ — Unmet amount of state RPS requirement.
- $\text{St_CSPRPS_shortfall}_{states}$ — Unmet amount of state CSP requirement.
- $\text{Oper_Res_Req}_{rto,m}$ — Operating reserve capacity required in rto m .